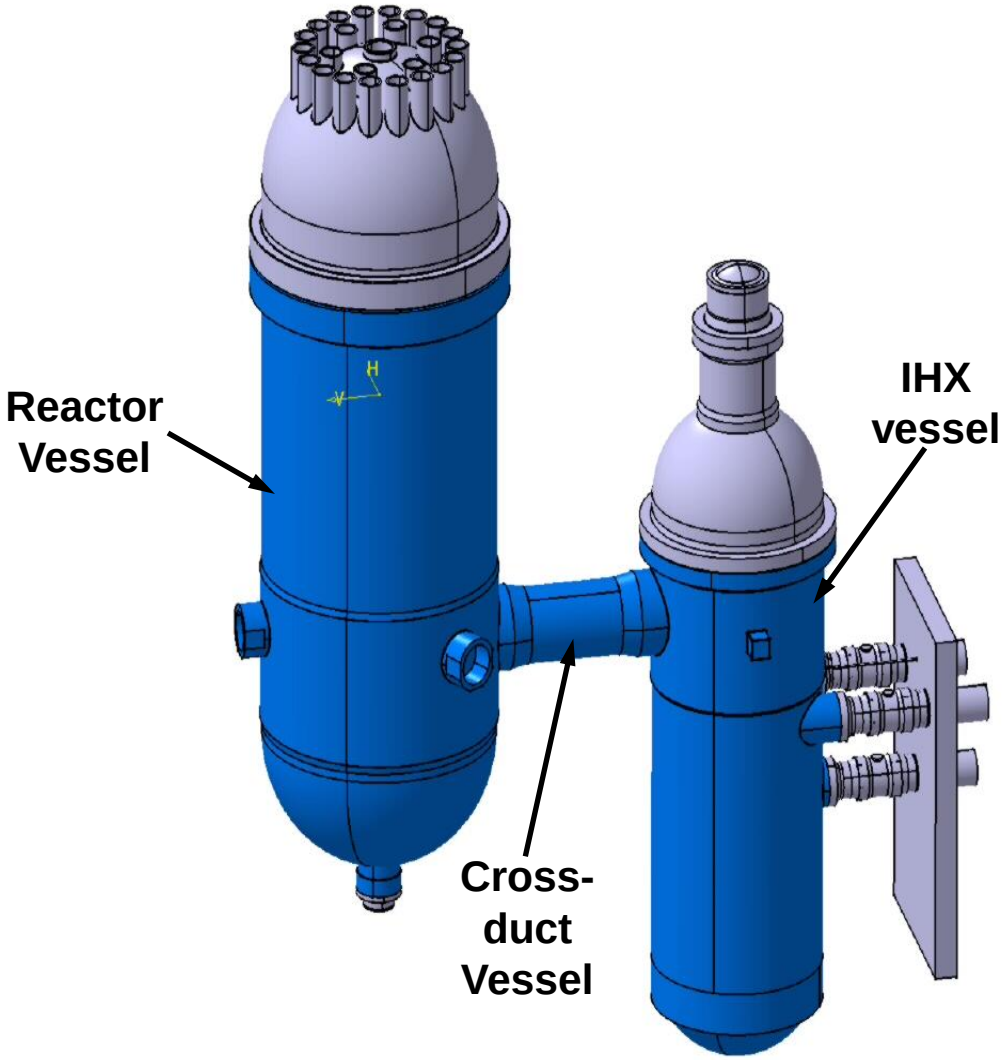
The HTR/VHTR Project in Framatome ANP

Dominique HITTNER

HTR-VHTR Project R&D manager
Framatome ANP

The reference concept of ANTARES programme: a flexible heat source for heat supply, electricity production or cogeneration

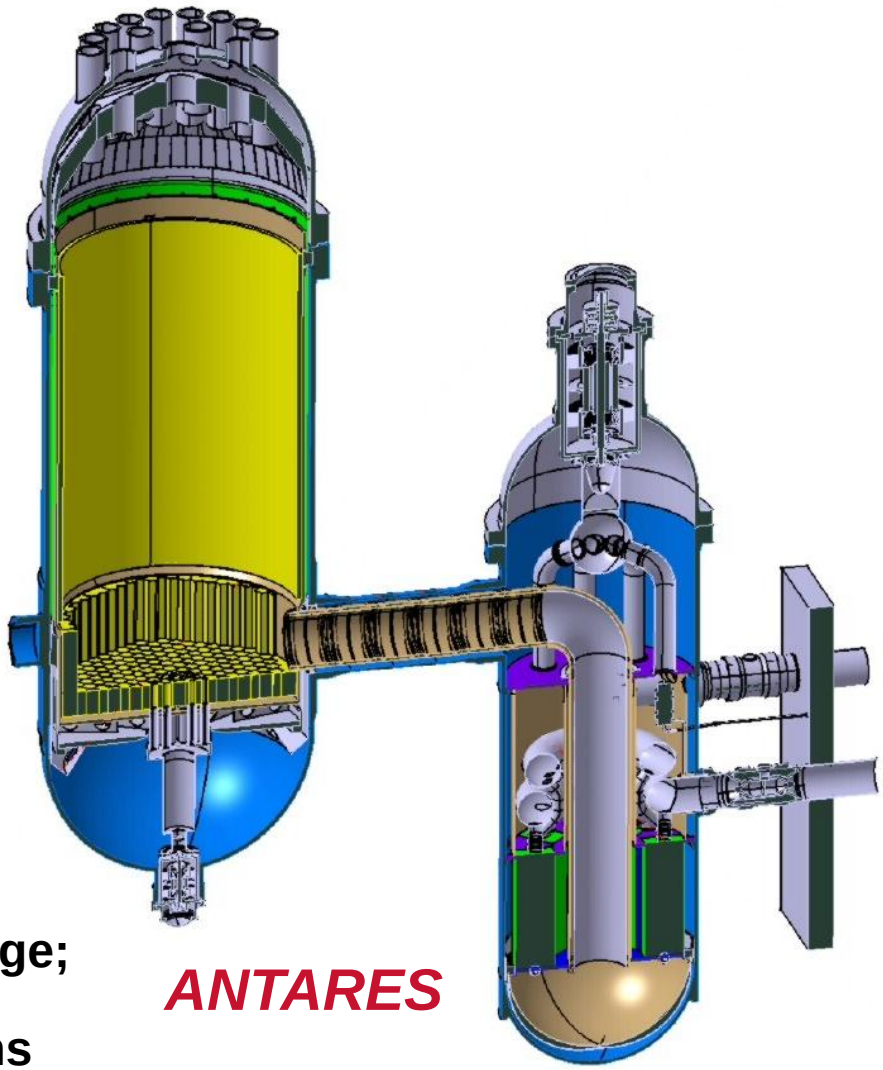
Base options of the Framatome ANP design



ANTARES

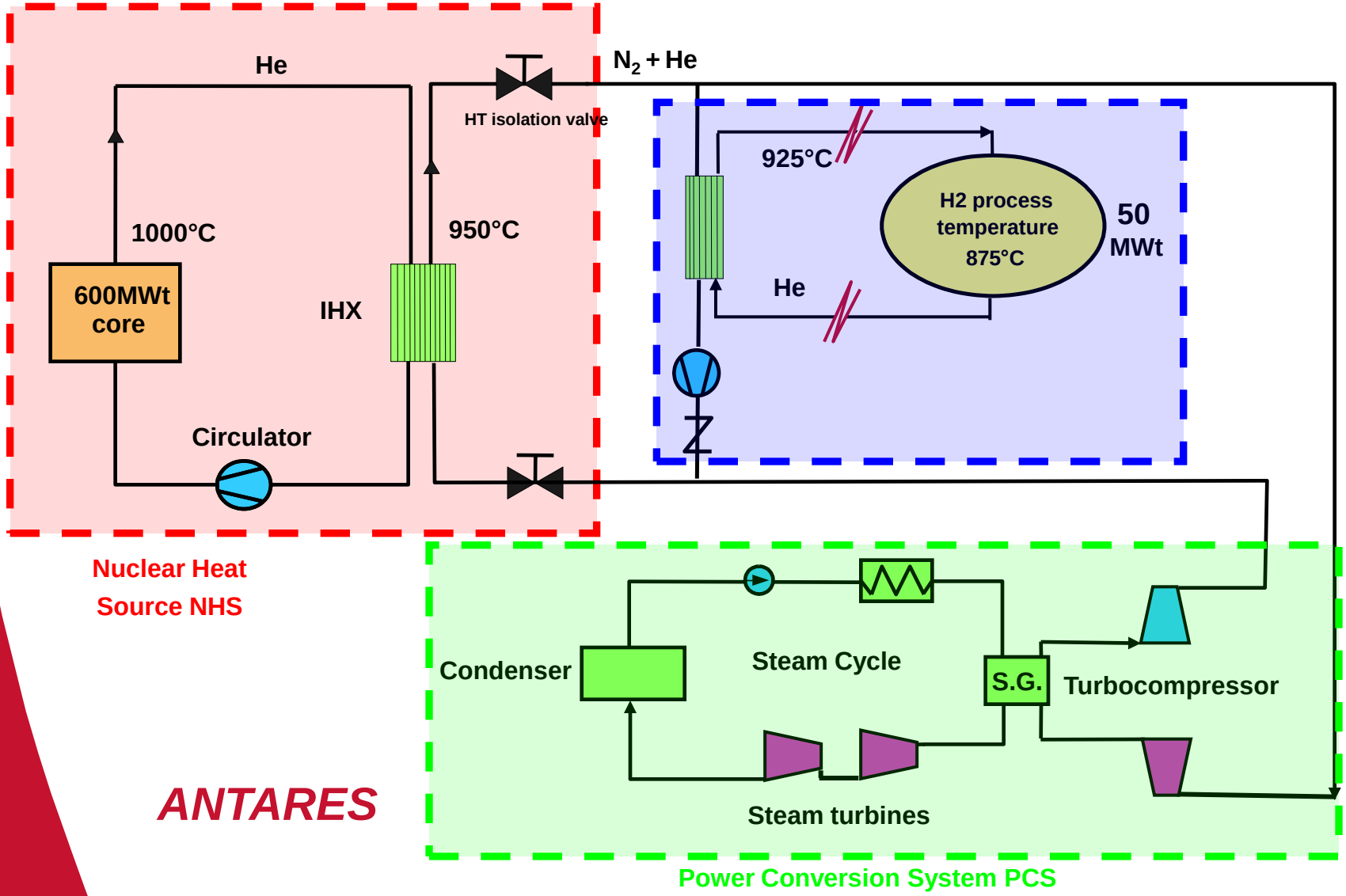
Indirect cycle

- **Indirect combined cycle**
  - **Same efficiency as direct cycle (~ 48%)**
  - **Minimises the development risks (vessel (t° + pressure) + turbo-machine)**
  - **Simplifies the turbomachine maintenance**
  - **Focuses the innovation effort on the IHX, which anyway has to be developed for heat applications**
  - **Flexibility for testing different types of applications (e.g. supercritical CO_2 cycle,heat applications, including H_2 production, etc) due to the decoupling with the reactor**
- **Plate IHX (back-up tubular)**
  - **Compactness and efficiency, but a real development challenge; FANP is at the same time investigating 3 different designs**



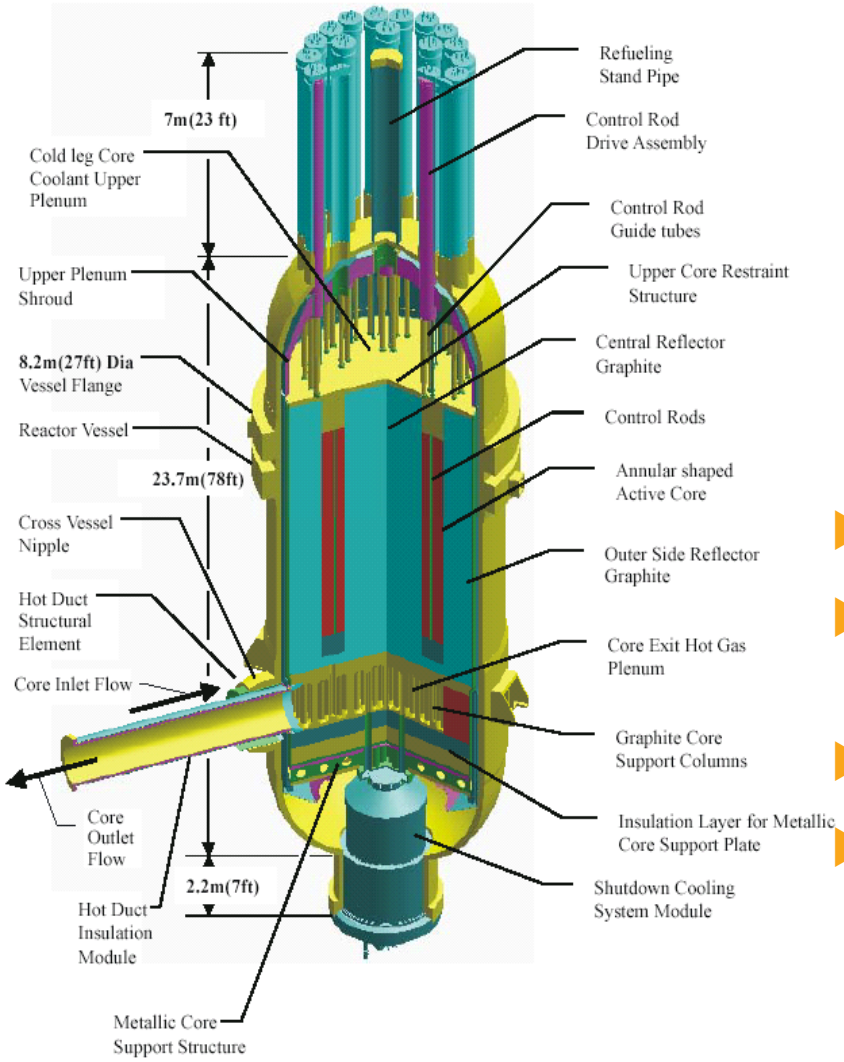
ANTARES

Arrangement for Electricity and Hydrogen Cogeneration



ANTARES

The reactor



ANTARES

- **TRISO fuel**
- **Prismatic fuel elements**
- **Annular core**
- **to make the largest use of inherent safety features**
  - **fuel leaktightness,**
  - **thermal inertia,**
  - **strongly negative temperature coefficient**
  - **Passive heat removal**

Performance objectives

- **Power: as high as compatible with inherent safety features, likely in the range of 600 MWth,**
- **Reactor outlet temperature: as high as reasonably possible for a near term deployment, likely to be at least 850 °C,**
- **Costs: as low as possible (construction, operation and maintenance, dismantling),**
- **Burn-up: optimised for making the fuel cycle cost effective while keeping compatibility with inherent safety features (most likely not exceeding ~ 150 GWd/tHM),**
- **to meet the licensing criteria in US, Europe and if possible worldwide, thanks to an effort of internationalisation of the safety assessment principles**

Framatome ANP Project integrating work

Internal FANP Activities

- **Reactor Engineering**
- **Fuel Plant Engineering**
- **Safety Approach**
- **R&D**
  - **Calculation Tools & Methods**
  - **Fuel Design & manufacturing**
  - **Materials** *Vessel, IHX...*
  - **Components** *IHX, Ducts, Valves*
  - **Helium Technology**

Past Experience in Germany (FANP, Jülich...)

- **AVR, THTR**
- **PNP, HTR-Modul Projects**
- **KVK Test Facility**

CEA R&D support programme

- Calculation Tools & Methods
- Fuel Technology
- Materials
- Helium Technology
- Test Facilities

EC Contracts

- FP5:
  - ✓reactor physics,
  - ✓Fuel technology
  - ✓materials,
  - ✓ components
  - ✓safety approach
- FP6: one large integrated project

Technology Supply

- HTR-10 China
- PBMR South Africa

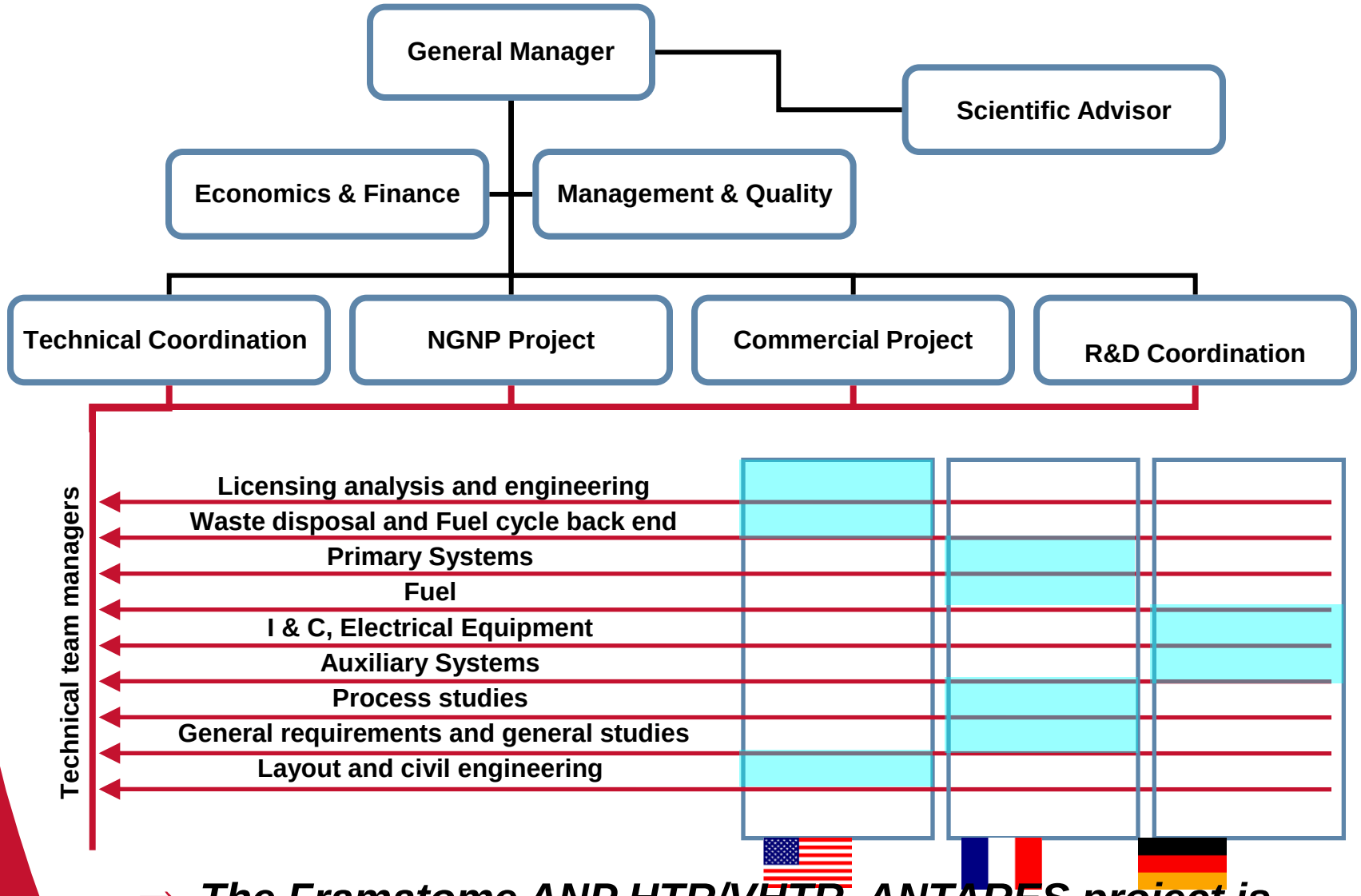
EDF Collaboration

- PCS Optimization
- HTE Process
- O&M

DOE/Minatom GT-MHR Programme

Support of Conceptual Design

V/HTR Project Organization



⇒ ***The Framatome ANP HTR/VHTR ANTARES project is an international project***

The R&D support programme

The R&D programme (1/2)

- **Development and qualification of computer tools**
  - Core physics (coupled neutronic and thermo-fluid dynamics tools)
  - Fuel performance
  - Transient analysis
  - Graphite oxidation
  - Seismic analysis of a block stack
- **Fuel technology (fabrication and behaviour in operating and accident conditions)**
- **Material development**
  - Vessel material
  - High temperature metallic materials
  - Graphite
  - Composites

  - Characterisation
  - Behaviour under irradiation
  - Oxidation

The R&D programme (2/2)

- **Helium technologies**
  - **Purification**
  - **Interaction with He impurities**
  - **Tribology**
- **Component development**
  - **IHX**
  - **Circulator**

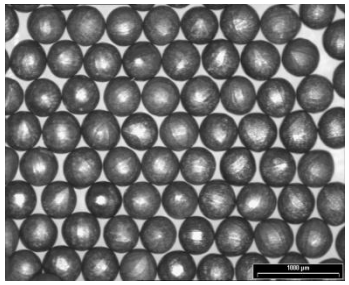
⇒ **Need to develop test facilities**

  - **Irradiation facilities (in OSIRIS, HFR)**
  - **Oxidation facilities (CEA, FZJ)**
  - **Helium test benches**
    - **Dedicated test facilities (impure He chemistry, He leak tightness of seals, insulation performance, purification, tribometer....)**
    - **Large integral test facility: HELITE loop developed in Cadarache, starting in 2007**
  - **...**

Fuel fabrication

CEA Cadarache

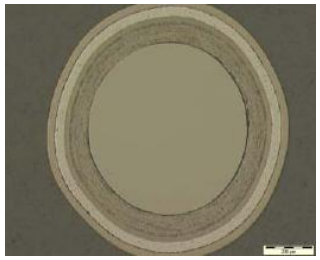
Vertically GSP device



UO_2 kernels

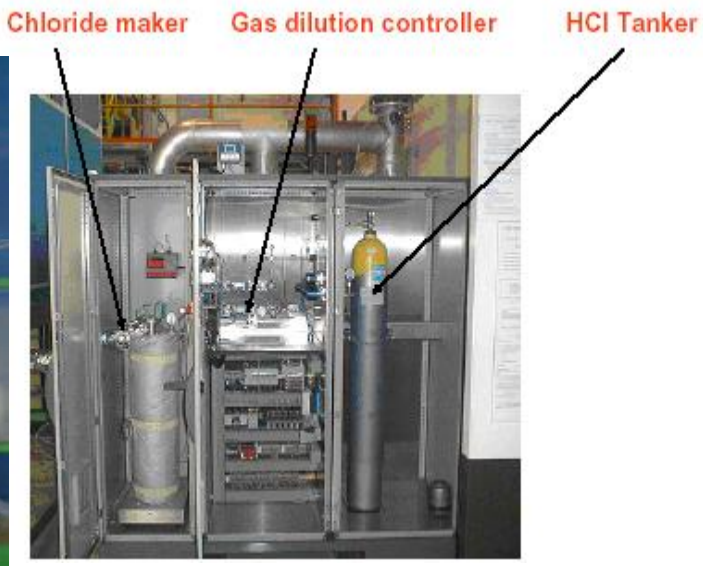
CEA Grenoble

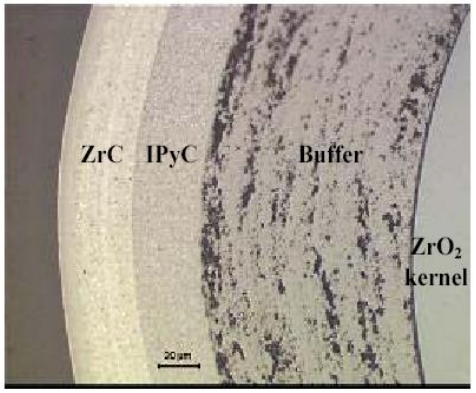
CVD furnace



TRISO Buffer/IPyC/SiC/OPyC layers

$ZrCl_4$ equipment for ZrC coating

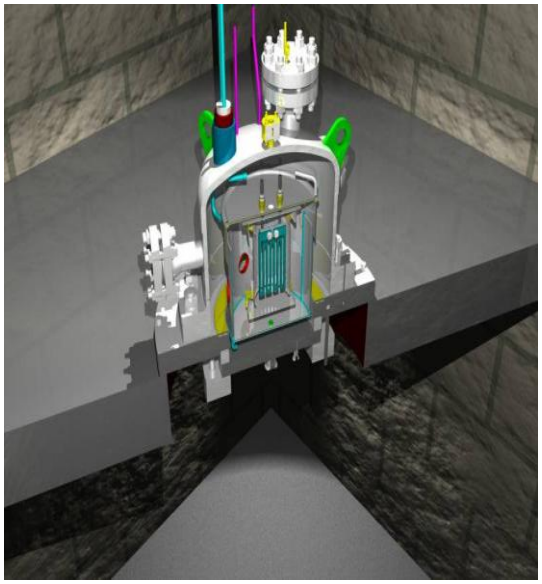




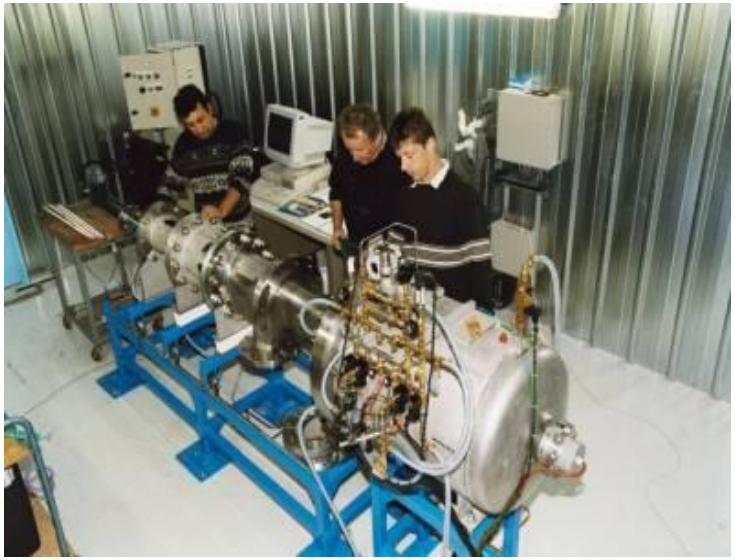
ZrC coating first tests

GAIA facility under construction in CEA Cadarache
+ Compacting facility from CERCA
1st UO_2 TRISO fuel re-fabricated in Europe in 2005
1st irradiation in OSIRIS in 2007

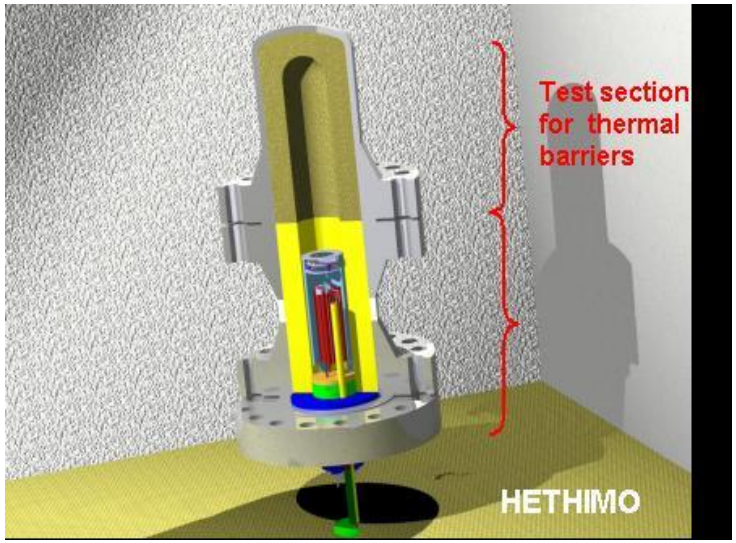
A few facilities in CEA Cadarache

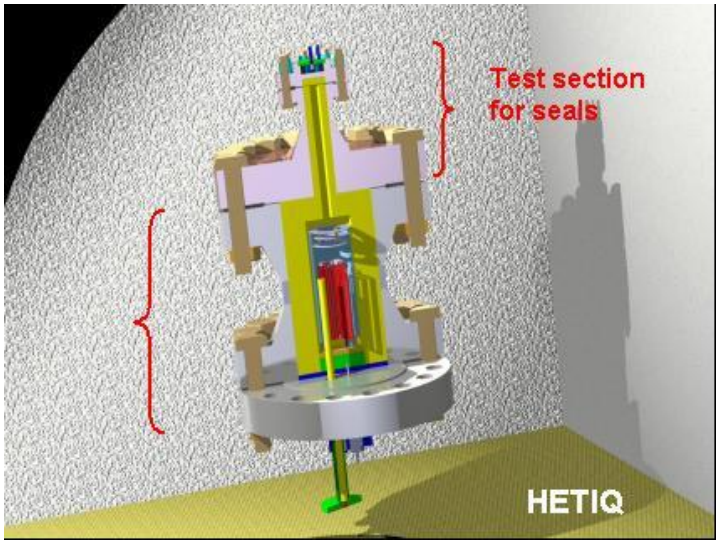


COMETHE Facility

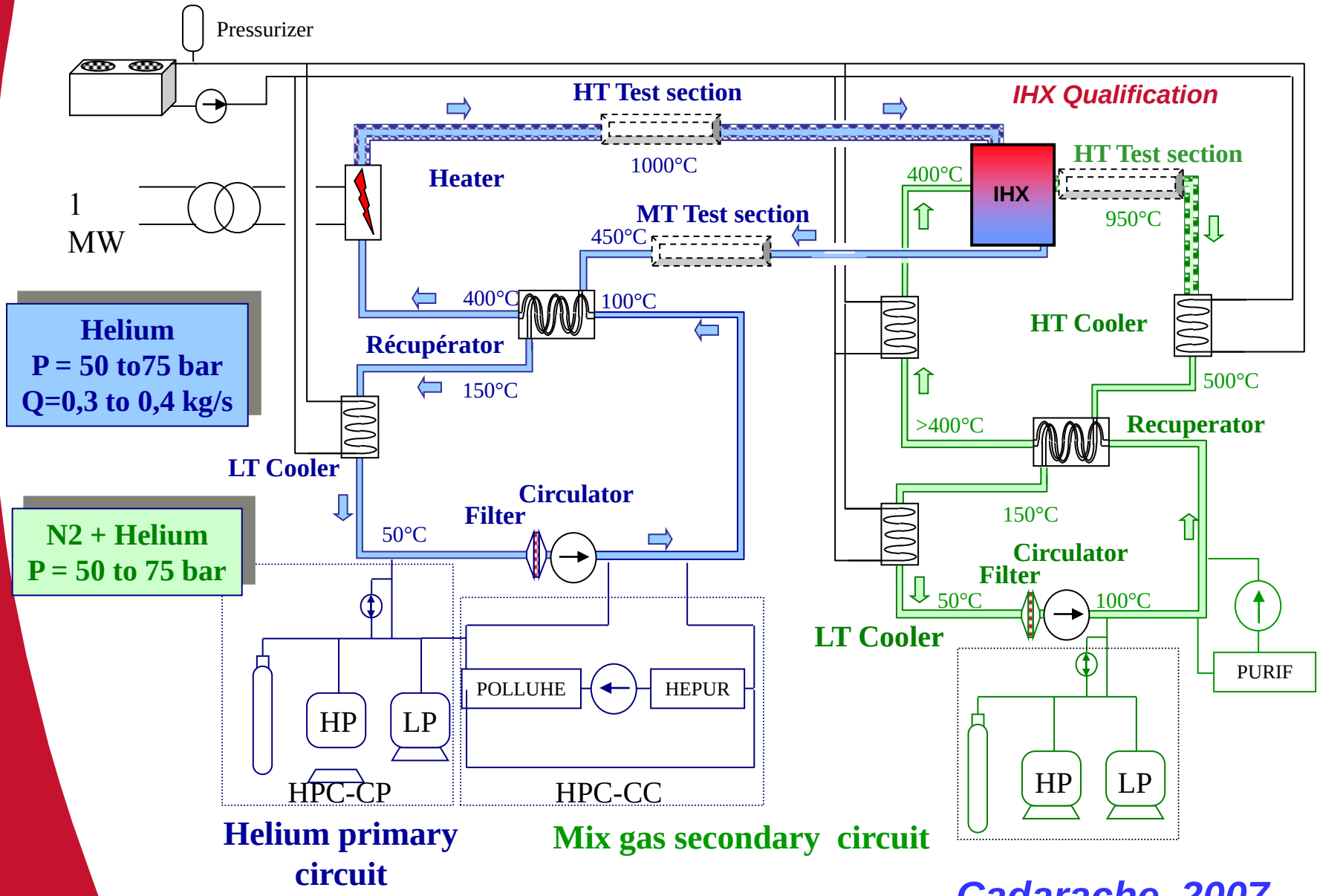


Helium Tribometer



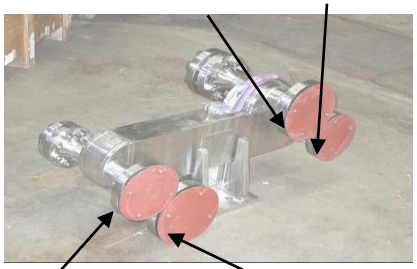


HELITE technological loop – 1 MW

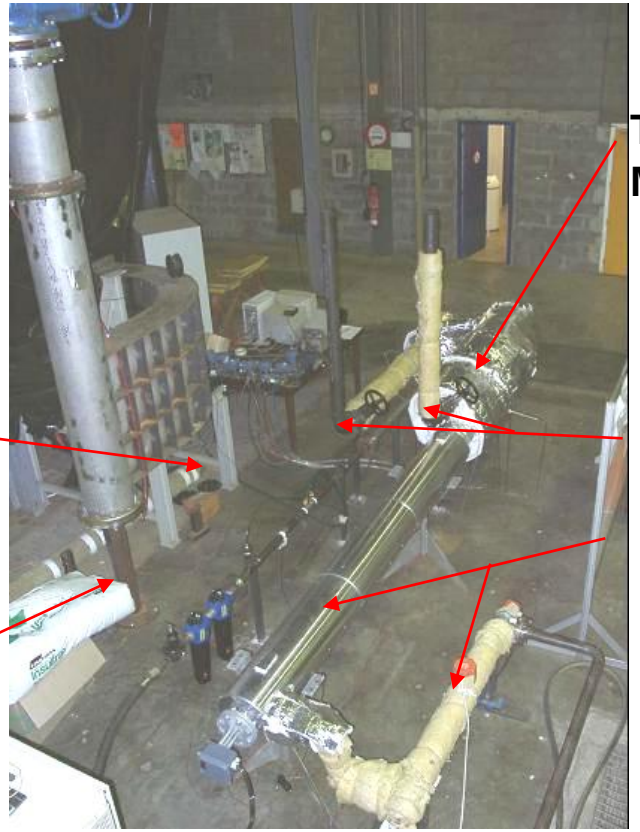


Cadarache, 2007

Framatome ANP has initiated a 3 Year IHX Development Program

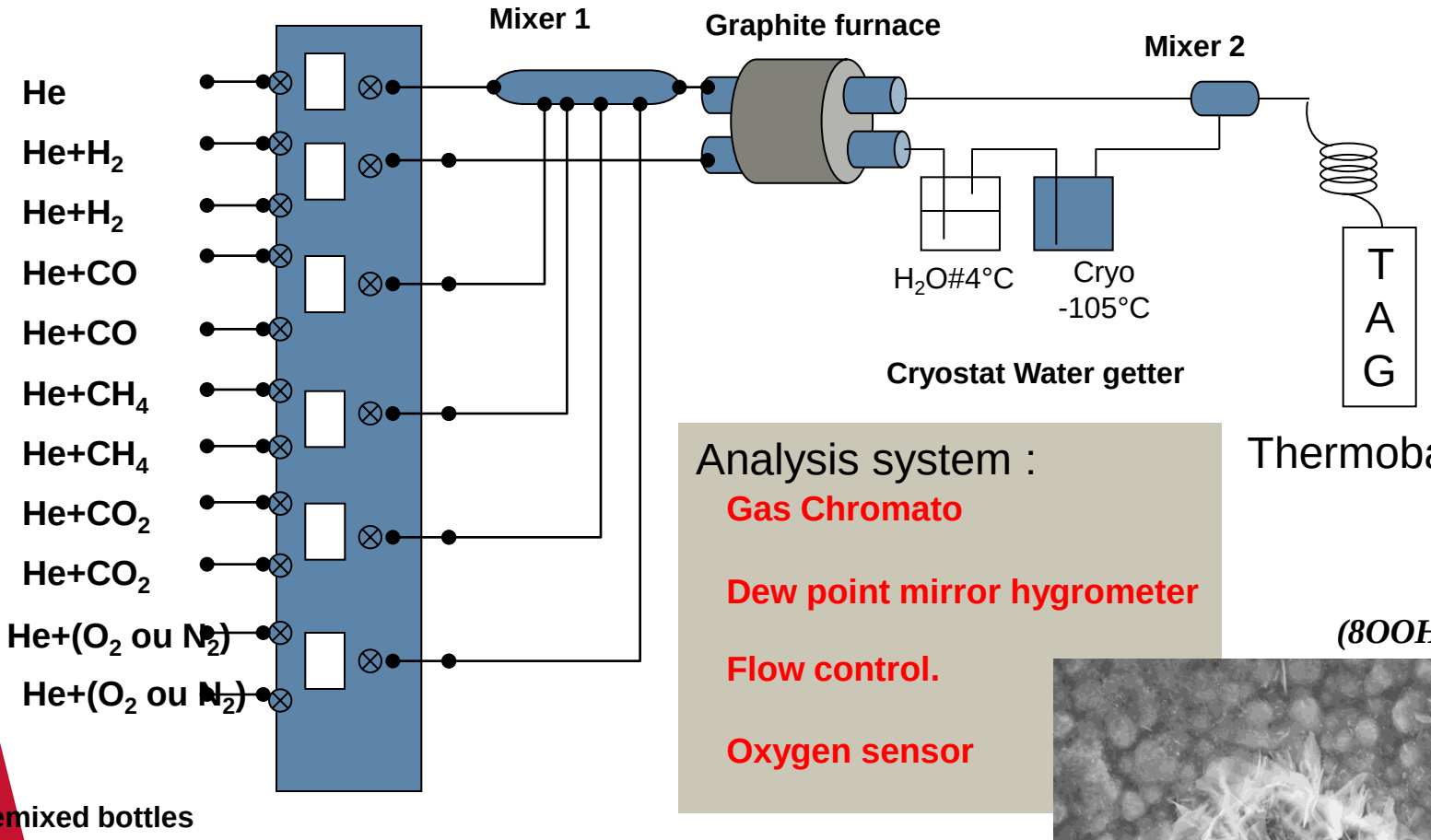


Framatome/HEATRIC IHX Test Module



Framatome ANP Test Loop with Framatome/HEATRIC Element

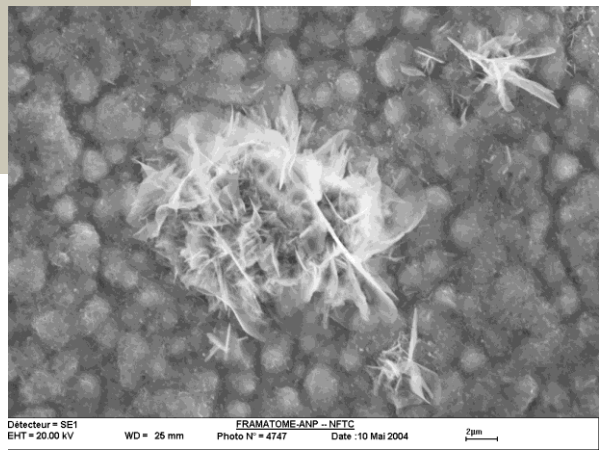
Behaviour of high temperature materials in He environment: the Framatome-ANP loop



Analysis system :

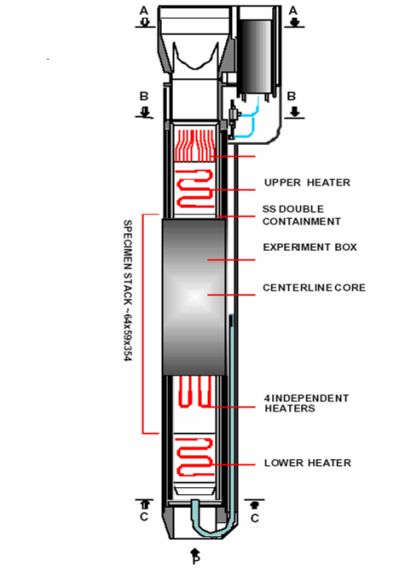
- Gas Chromato
- Dew point mirror hygrometer
- Flow control.
- Oxygen sensor

(8OOH at 800°C)

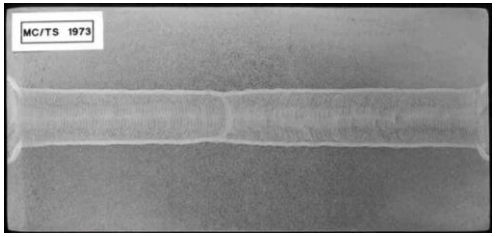


Vessel material: Mod. 9Cr1Mo development

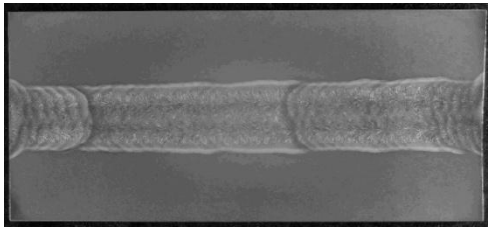
- **Behaviour under irradiation: PIE of HFR irradiation just finished ⇒ no significant impact of irradiation on base material and thick weldment**
- **Welding development (FANP)**



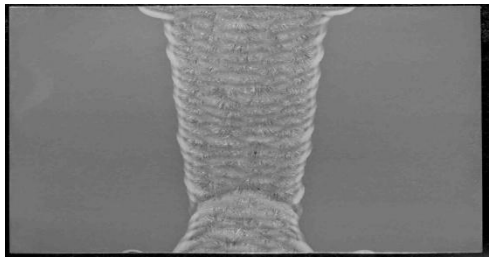
Initial GTAW testing: hot cracking



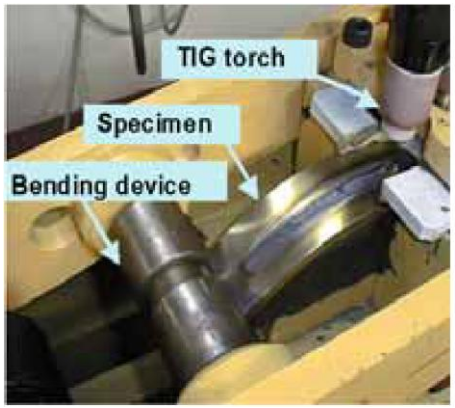
GTAW



SAW



SMAW



Varestraint Tests (CEA)

An overview of the Framatome ANP + CEA + EdF HTR/VHTR programme

- **Total 2004 HTR-VHTR budget (FANP + CEA + EdF) ~ 32 M€/y**
- **Total 2004 R&D effort (FANP + CEA + EdF) ~ 20 M€/y**
- **Total 2004 Framatome ANP budget ~ 20 M€/y**

⇒ **Framatome ANP is committed to develop HTR/VHTR till industrial deployment and is leading the programme performed with its partners**

- **But the FANP/CEA/EdF partnership cannot do it alone !**

✚ **Importance of the R&D in the present phase**

- **Need of international cooperation (Europe, GEN IV...)**